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RESEARCH MANPOWER REQUIREMENTS ARISING FROM ACCELERATED EXPENDITURES ON R&D

Ministry of State
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SUMMARY AND CONCLUSIONS

The purpose of this paper is to develop several scenarios of requirements for professional R&D personnel associated with raising the level of R&D in Canada. The analysis is confined to scientists and engineers in the natural sciences, consistent with the current national estimates of gross domestic expenditures on research and development in the natural sciences and engineering (GERD). The analysis limits itself to university-trained research personnel, mainly because of the long time involved in their training. Technicians and technologists are also required as support staff, but estimates on their needs are not given in this report. It should be noted, however, that the supply of support staff is much more flexible due to shorter training requirements.

The balance between supply and demand cannot be projected in precise numbers because it depends on a number of events that can be affected by changes in policies, programs, processes and approaches. The analysis is carried out for a number of scenarios that serve to illustrate the implications of various assumptions rather than to project or predict what would actually happen.

The main implication arising from these simulations is that, under the more plausible sets of assumptions, there would be shortages of trained researchers, especially for researchers in the applied fields of science in industrial research areas. The extent of the shortages would be a function of the size of the GERD target, the time at which it is supposed to be attained, the growth in the amount of R&D performed by the average researcher, the length of time researchers remain in R&D careers, the number of research trained personnel coming out of the university system, and the extent to which industry would switch to Ph.D.s and M.A.s in R&D jobs.

Any shortages would have to be made up by:

- on the job research training programs by industry;
- stimulating university enrolments in applied sciences graduate programs, by the emergence of new research jobs and careers in industry;

- selective increases in immigration, and the strategic use of immigrants to transfer knowledge and skills to Canadians; and
- further increases in the manpower training programs by the granting councils.

The achievement of a higher GERD target is predicated on a number of factors that would require careful planning and management. An ambitious GERD target, or a target aimed at a very early date, or failure to attract and retain researchers, or failure to attract and train sufficient numbers of new researchers, would soon result in shortages of research personnel, especially in the applied sciences. On the other hand, a continuation of the low level of GERD that now prevails will result in surpluses of research trained graduates, unless there are further sharp declines in graduate enrolments at Canadian universities. Such declines, however, would further aggravate the problems and shortages of Canada's R&D capacity.

INTRODUCTION

This paper considers several possible scenarios of requirements for professional R&D personnel associated with raising the level of R&D in Canada. The scenarios are collectively referred to as R&D "targets" in the sense that they all are directed towards a "target" distribution of R&D performance in the end-year, when industry performs a substantially larger share of the total than at present.

Requirements for research trained personnel are calculated by performer of R&D (i.e. governments, industry and the universities), and by broad field of study within the natural sciences (applied sciences, and other natural sciences). The term "requirements" refers to the number of university graduates needed to fill job openings in professional R&D occupations, mainly in the engineering, physical, and life sciences. Additionally, an attampt is made to identify potential imbalances of supply and requirements that may occur as a result of raising the level of R&D.

The analysis relates to R&D in the natural sciences, as measured by the national statistics on gross domestic expenditure on R&D (GERD), and the professional research manpower associated with this activity. Among the most important assumptions are the level of R&D attained, expressed as a percentage of industrial R&D increases relative to government and university-based R&D, and the future supply of researchers.

Although the projections may have the appearance of a forecast, it is important to bear in mind that they are not forecasts since the analysis explores several possible scenarios with a view towards quantifying the range of manpower requirements associated with these alternatives.

The R&D manpower analyses build on the work that the Ministry has done in the area of highly qualified manpower, as it relates to science policy and university-based research. To some extent, it uses the MOSST highly qualified manpower model and data base (HQM Model) which provides projections of requirements for university graduates by field of study and degree level based on projections of occupations, and projections of the educational distributions of new entrants to these HQM occupations.

GERD TARGET

The main reason for the low proportion of GERD in Canada's GNP is the shortfall in industrial R&D. The need to increase the level of R&D, particularly industrial R&D, has been agreed upon by the federal and provincial governments, the Lamontagne Senate Committee on science policy, the Science Council, and by many professional associations.

Canadian firms, and especially foreign owned ones, have traditionally found it to their advantage to acquire technology outside Canada. This situation has been perpetuated through the existence of small markets for Canadian products. If the R&D necessary to develop the technology that is now purchased abroad were carried out in Canada, a sizeable portion of the gap in the existing industrial R&D would be closed.

Canadian industry will undertake to perform significantly more R&D when the markets for its products have expanded, and when there is the necessary inducement to become internationally competitive through investment in R&D and the development of new technology. Several measures have been put into place in recent years to improve the competitiveness of Canadian products, such as the gradual introduction of commercial and trade policies that open up foreign markets for Canadian firms and that allow more competition in the Canadian market between Canadian and foreign products.

Taken as a whole, these policies should result in better opportunities for profitable R&D investments and at the same time increase pressures through competition on the domestic market to improve productivity and technological change. As well, there have been efforts through tax policy and government procurement policy to directly stimulate industrial R&D in Canada. In quantifying the GERD target, it is assumed that most of the increases in research will, therefore, be performed and funded by industry, with governments and the universities also increasing their R&D, but at a significantly lower rate of growth. The target distribution assumes that industry will perform 65 percent of GERD as compared with 43 percent at present. This target share is similar to that of other prominent industrial countries such as the United States, Japan and Germany.

ASSUMPTIONS UNDERLYING THE PROJECTIONS

Requirements for research personnel arising from the R&D target levels are based on a number of assumptions. The size of the requirements, and any imbalances that may occur, are dependent on a number of factors:

- The target level, the year in which the target is reached, and the speed with which it is approached. This study assumes several target levels and dates that are to be approached at a constant annual rate of increase. Obviously, the shorter the time, or the higher the target, the greater the annual requirements for researchers. Four scenarios are developed and compared:

  - continuation of the current level of R&D spending (0.95 percent of GNP);

  - increase in the level of R&D expenditures to 1.5 percent of GNP by 1985;

  - increase in the level of R&D expenditures to 1.5 percent of GNP by 1990; and

  - increase in the level of R&D to 2.5 percent of GNP by 1990.

- The rate of increase in real GNP, since the target is related to the size of GNP. It is assumed that GNP will increase in real terms at an average annual rate of 3 percent per year. Higher rates of growth would increase the number of researchers required. Of course, R&D improves productivity and output growth, but at this stage this feedback effect from higher R&D on productivity changes is not taken into account in an explicit way.

- The extent to which the amount of real R&D resources per researcher (i.e., the R&D/researcher ratio) increases. The higher this rate of growth, the lower the requirements for researchers. There is a need for growth, because in moving to a significant expansion of the R&D effort there would have to be more expensive and sophisticated research equipment,

increased use of technical and other support staff to back up professional researchers, and general increases in the scale and size of research projects which may combine several small scale individual efforts into more efficient team projects. This study assumes three sets of growth rates in the amount of real R&D expenditures per researcher: 3 percent per year, 1.5 percent, and no growth. The 3 percent figure is consistent with the historical productivity growth experience in the private sector at large, but the limited evidence available for the R&D sector indicates historical growth rates in the amount of constant dollar R&D performed per researcher that are much lower than the productivity growth rates achieved by the private sector of the economy at large. In fact, over the past decade, there has been no increase in such expenditures.

- The rate of attrition and the productive research life span of researchers. The analysis assumes an attrition rate of 1.5 percent of the stock per year. This rate is derived from an analysis of S&T occupations in the HQM Model and Data Base and reflects the youthful age structure of persons currently in these occupations. Regarding the length of R&D careers, two scenarios are tested. The first assumes that researchers remain in their careers and do not shift into other work functions. This may, however, not be a realistic assumption. For example, in the experience of NSERC, the average university researcher works at R&D for about 10 to 20 years and then moves on to other activities, although one could argue that this may no longer be true in today's university setting where there are fewer mobility opportunities. An additional assumption involving a reduced R&D work life or career span is, therefore, also tested. For purposes of that simulation, a 15 year average R&D life span per scientist is used.

- The size of the industrial R&D sector. The main shortfall in the Canadian R&D effort lies in industrial R&D. A target distribution of GERD by performer is assumed such that industry performs 65 percent of R&D by the end-year, and the shares of the other performers decline proportionately.

- The composition of R&D. The analysis assumes that 60 percent of industry's additional manpower requirements, and 50 percent of the requirements in the other sectors, will be in the applied sciences.

- Degree level of new R&D staff. Most professional R&D staff in government and at universities have graduate research training. In industry, on the other hand, only about one-third of the professional R&D work force currently has graduate training. Canadian industrial R&D, with some significant exceptions, consists to a great extent of adapting R&D break-throughs originating abroad. If there is to be a quantum jump in Canadian industrial R&D, then there may well be a need to staff the R&D projects with persons specifically trained in research techniques and skills. Such training takes place at the graduate level. While it is entirely possible -- and even practical -- to substitute persons with undergraduate degrees, say engineers, to staff industrial R&D positions, there could be a limit to the extent to which this would be possible.

- The enrolment of students in the natural sciences and engineering. Enrolments in these fields have not changed from the levels of the early 1970s. As well, enrolments of foreign (visa) students have increased generally, and particularly in the applied sciences. This means that the number of graduates available in the Canadian labour market has declined even more than would be indicated by the declines in enrolments. The support programs of NSERC are intended to slow and reverse the trend in enrolment declines. Also, job prospects due to actual increases in R&D expenditures would stimulate enrolments. For the purpose of this analysis it was assumed that, on the average, the annual number of graduate degrees granted would, therefore, not fall below the current level, and the available supply to the labour market would remain at this level to the end-years of the projections. If today's level is not maintained, the gap between supply and requirements would be larger.

- The analysis assumes that the current (1977) level of immigration will be maintained throughout the forecast period. Many future imbalances will depend on the strategic use of immigration to transfer knowledge and skills to Canadians.

- The higher the proportion of applied scientists needed to carry out the research, the more acute will be the shortages, since the current capacity of the universities to produce graduates in the applied sciences is limited, and applied graduates are already in high demand on the current labour market.

- The extent to which graduates from recent years who have not yet obtained employment in their specialty can be drawn into R&D jobs. If at all, this would provide staff in the early years, but it is doubtful that there are all that many graduates in this situation[1]. Also, research skills are quickly lost if not practiced. This study does not take this supply source into account.

PROJECTION METHOD

There are three categories of demand for HQM over the projection period:

- Demand for non-R&D HQM manpower;

- Replacement demand due to attrition; and

- Demand for R&D HQM manpower.

The requirements for the first two categories are derived with the aid of the MOSST HQM Model. There is only one projection for the non-R&D manpower requirements[2]. Regarding replacement demand, an attrition rate of 1.5 percent is used, as derived from the age structure of the S&T manpower stocks in the HQM model. A simulation is also carried out with a 15 year work life assumption for researchers in R&D jobs.

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[1] The Statistics Canada Survey of 1976 University and College Graduates and the 1976 Doctoral Degree Recipients Survey both indicated generally low rates of involuntary unemployment and relatively high correspondence between field of study and employment at the graduate degree level.

[2] Cumulative non-R&D HQM manpower requirements are estimated at 12,750 for the period 1978-1985 and at 21,900 in the 1978-1990 time period. These estimates represent the difference between the total requirements for post-graduates in the natural sciences (from the HQM Model) and the requirements for R&D personnel under a "no-change" scenario in which the 1978 level and distribution of GERD is held constant over the projection period.

Regarding the requirements for R&D manpower, there are five projections, consistent with the target assumptions. The method employed to calculate requirements for R&D personnel is to relate the real R&D expenditures per researcher (R&D/researcher) to the total R&D expenditures assumed in the target scenarios, as shown in Table 1.

In particular, the level of R&D per researcher in each of the performing sectors is computed for 1978. This ratio is then projected to the end-year, under the various growth assumptions (3 percent annual growth, 1.5 percent annual growth, and no growth).

The R&D per researcher in 1978 varies slightly by performing sector, but is in the vicinity of $100,000. It is $90,918 in industry and $111,263 in the universities. Appendix Table A-3 shows the 1978 levels for the various sectors, and the projection of these levels under the 3 percent growth assumption, in constant 1978 dollars. For example, by 1985, under this assumption, the R&D per researcher would rise to $111,818 in industry and $136,839 in the universities.

This study distinguishes between the applied and other natural science fields of study. A major increase in industrial R&D and the personnel requirements arising from this increase would draw more heavily on the applied fields of study. For the purpose of this study the applied fields of study include engineering, agriculture, forestry, geology, meteorology, computer science, metallurgy and materials science, oceanography, and such related fields as health and veterinary medicine. In the projections, additional personnel requirements resulting from increased expenditures on R&D are allocated to applied and other natural science groups on a 50-50 basis for all performing sectors except industry, where it is assumed that 60 percent of the additional requirements would be in the applied fields of study.

REQUIREMENTS FOR RESEARCHERS

In 1978, it is estimated that there were some 21,800 researchers in the various performing sectors: about 10,000 in industry; 5,900 in the federal government; 5,000 in the universities[3]; and

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[3] In full-time equivalent faculty man years estimated to be devoted to research as distinct from other functions such as teaching. For more details on the estimation method, see MOSST Background Paper No. 16, "The Stock of Research Trained Personnel".

TABLE 1

GERD BY PERFORMER

(millions of constant 1978 dollars)

	1978	1985		1990		
GERD SCENARIOS	0.95/78	0.95/85	1.5/85	0.95/90	1.5/90	2.5/90
Federal Government	607	408	645	471	747	1,245
Provincial Governments	73	80	126	92	146	244
Industry	928	1,750	2,763	2,018	3,203	5,339
Universities	555	438	691	505	802	1,336
Private non-profit	15	16	25	18	29	49
TOTAL GERD	2,178	2,692	4,250	3,104	4,927	8,213

DISTRIBUTION OF GERD

	1978	End-Year Distribution in All Scenarios
PERFORMER	(%)	(%)
Federal Government	27.9	15.2
Provincial Governments	3.4	3.0
Industry	42.6	65.0
Universities	25.5	16.3
Private non-profit	0.7	0.6
TOTAL GERD	100.0	100.0

SOURCE: Based on data in Appendix Tables A-1 and A-2

Note regarding GERD scenarios: 1.5/85 means that GERD is assumed to be 1.5% of GNP in 1985, etc.

fewer than 1,000 in other sectors such as the provincial governments. The increases in the stock of researchers, according to the assumptions and the methodology explained in the preceding two sections, are a function of the size of the GERD target (.95 percent, 1.5 percent, or 2.5 percent of GNP); the time at which the target is achieved (1985-1990); and the growth in the R&D/researcher ratio (3 percent; and no change). The stocks required for these scenarios are shown in Table 2.

The required stock rises from 21,800 in 1978 to 36,000 in 1985 in the 1.5 percent GERD target, given that the R&D/researcher ratio can be increased at 3 percent per year. This would require a considerable change in the efficiency and management of the research effort, given that over the past decade the ratio has remained more or less constant. Thus if this situation were to prevail until 1985; i.e. if there were no improvement in the R&D/researcher ratio, the stock of required researchers is estimated to be considerably higher under this target, i.e. 44,300.

Similar relationships between the required stocks and the growth of the R&D/researcher ratio apply to other GERD scenarios, as shown in Table 2. For example, the required stock rises from 60,000 to 85,600 in the 2.5/90 scenario if the R&D/researcher ratio were not to increase at 3 percent per year. Even maintaining the current 0.95 percent GERD ratio to 1990 would imply more researchers (an increase from 21,800 in 1978 to 32,400 in 1990) if there were no change in R&D/researcher. The impact on the stocks required due to improvements in R&D/researcher illustrates the potential benefits that can be obtained by management of the research effort.

A further source of requirements for new researchers that has to be taken into account is replacement demand due to attrition, and due to occupational shifts out of research occupations into other functions such as management, administration, or other professional occupations. As noted, the calculations for this study use a 1.5 percent attrition rate, a rate that is based on the actual (rather youthful) age structure of Canadian researchers now in the labour force, and two assumptions about working career: no shift out of an R&D career once a person has entered it; and shifts out of research into other occupations after an average of 15 years.

TABLE 2

REQUIREMENTS FOR R&D MANPOWER

	1978 Stock	FUTURE STOCK REQUIRED IF: Target is reached in 1985		Target is reached in 1990		
GERD SCENARIOS		0.95/85	1.5/85	0.95/90	1.5/90	2.5/90
		(thousands of persons)				
3% growth in R&D/ researcher	21.8	22.7	36.0	22.7	36.0	60.0
No growth in R&D/ researcher	21.8	27.9	44.3	32.4	51.4	85.6

SOURCE: Appendix Table A-4

The number of additional researchers over the entire projection period, for all scenarios and taking account of all these factors described, is shown in Table 3.

For the entire 7-year period from 1978-85, in the 1.5 percent GERD target, the number of new researchers required is estimated to range from 29,740 to 49,050, depending on a combination of factors. Increases in the R&D/researcher ratio, and success in retaining researchers in R&D careers over the projection period, will reduce the number of additional requirements. Lack of growth in R&D/researcher, and inability to keep researchers in R&D careers, will sharply increase the number required. This relationship holds for all the GERD target scenarios shown in Table 3, and points to the importance of attracting and retaining scientists in R&D careers.

The largest increases in GERD are required in industry, where the majority of researchers are from the applied rather than other than applied fields of study. Table 4 shows the differences in requirements under the highest and lowest GERD scenarios for applied and non-applied researchers.

The numbers required above the 0.95 percent GERD level are provided in Table 5, by performing sector. (Only the highest and lowest combinations are shown for the GERD scenarios.) Most of the growth in numbers, under all scenarios that are based on a higher GERD ratio, would have to take place in industry. Of the total of 13,868 new researchers needed over the 7-year period from 1978-85 in the 1.5 percent GERD scenario with 3 percent increase in R&D/researcher, and no occupation shifts out of R&D careers, industry would require 9,472, with the federal government and the universities each requiring close to 2,000. Similar relationships between the requirements by industry and the other performers exist for the various scenarios (see Table 5).

SUPPLY OF PH.D.S AND M.SC.S

For total natural sciences and engineering, there was very little change in the number of graduate degrees awarded from 1972 to 1977. The number was about 4,000 masters and Ph.D.s per year. However, the number of part-time students, who usually are already members of the labour force, had significantly increased and the number of immigrants with degrees had declined over this period.

TABLE 3

NUMBER OF ADDITIONAL RESEARCH PERSONNEL REQUIRED

UNDER VARIOUS ASSUMPTIONS

(Cumulative Number of Additional Researchers required)*

	1978-85		1978-90		
GERD SCENARIOS	0.95/85	1.5/85	0.95/90	1.5/90	2.5/90
3% growth in R&D/researcher, and 1.5% attrition	15,875	29,740	26,695	41,020	66,555
3% growth in R&D/researcher, 1.5% attrition, and 15 year work life	26,605	40,475	45,095	59,420	84,955
1.5% growth in R&D/researcher, and 1.5% attrition	18,435	33,780	31,405	48,420	78,770
No growth in R&D/researcher, 1.5% attrition	21,310	38,320	37,095	57,355	93,545
No growth in R&D/researcher, 1.5% attrition, and 15 year work life	32,045	49,050	55,490	75,755	111,930

SOURCE: Estimates by MOSST

Note on GERD Scenarios: 1.5/85 means that GERD is assumed to be 1.5% of GNP in 1985, etc.

NOTE(*): The underlying stock figures for the 3% and no growth, R&D/researcher ratio, for the various GERD targets, is shown in Appendix Table A-4.

TABLE 4

NUMBER OF RESEARCHERS REQUIRED IN APPLIED AND OTHER THAN APPLIED NATURAL SCIENCES

(Cumulative Totals)

		1978-85		1978-90		
GERD SCENARIOS		0.95/85	1.5/85	0.95/90	1.5/90	2.5/90
3% growth in R&D/ researcher, and 1.5% attrition	Applied Natural Sciences	11,530	19,410	19,165	27,300	41,810
	Other Natural Sciences	4,345	10,330	7,530	13,720	24,745
	TOTAL	15,875	29,740	26,695	41,020	66,555
No growth in R&D/ researcher, 1.5% attrition, and 15 year work life	Applied Natural Sciences	20,485	30,150	35,125	46,635	67,195
	Other Natural Sciences	11,560	18,900	20,365	29,115	44,735
	TOTAL	32,045	49,050	55,490	75,750	111,930

SOURCE: Estimates by MOSST.

Note regarding GERD Scenarios: 1.5/85 means that GERD is assumed to be 1.5% of GNP in 1985, etc.

TABLE 5

REQUIREMENTS FOR ADDITIONAL RESEARCHERS DUE TO

RAISING THE GERD TARGET ABOVE 0.95 PERCENT

(Cumulative Totals)

SECTOR	1978-85	1978-90	
GERD SCENARIO	1.5/85	1.5/90	2.5/90
1) 3% growth in R&D/researcher and 1.5% attrition			
Federal	1,973	2,055	5,705
Provincial	383	396	1,100
Industry	9,472	9,754	27,170
University	1,962	2,039	5,665
Private Non-profit	78	80	220
TOTAL	13,868	14,324	39,860
2) No growth in R&D/researcher, 1.5% attrition, and 15 year R&D work life			
Federal	2,415	2,895	8,055
Provincial	470	560	1,565
Industry	11,620	13,810	38,510
University	2,405	2,880	8,005
Private Non-profit	95	115	310
TOTAL	17,005	20,260	56,445

SOURCE: Estimates by MOSST.

When these factors are taken into account, it appears that the available new supply of persons with post-graduate degrees had declined by about 15 percent during the 1972 to 1977 period. The 1977 estimate of available supply was approximately 3,700. (Appendix Tables A-5 to A-7.)

In the applied sciences and engineering (including health and the applied life and physical sciences), degrees awarded increased in 1977, after five years without any growth. However, adjusted for the above-noted factors, the available supply of applied science graduates shows a decrease of about 8 percent since 1972, mainly due to reduced immigration. The 1977 level of available supply was about 2,350.

The annual number of degrees awarded in the other natural science fields of study (life, and physical sciences and mathematics), has declined by 14 percent since 1972. Due to falling immigration, available supply declined even more (by 26 percent). The 1977 level of available supply was approximately 1,320.

Table 6 summarizes the trends in the available supply of graduates.

The universities are constrained financially, and face pressures to rationalize and adapt to emerging circumstances. Graduate enrolments in the natural sciences have been on a declining trend in recent years and, without counter measures, would continue to decline.

Looking to the 1980s, university enrolments are expected to decline. This has already begun to place financial pressure on the universities. There may need to be staff reductions, and employment prospects and mobility in university teaching and research may become increasingly limited. In this period of constraint, the universities may have difficulty in adapting facilities and teaching staff as rapidly as would be desirable to meet increased student interest in particular fields of study, and to reduce staff in fields that will be experiencing enrolment declines.

NSERC has recognized the emerging dangers to the capacity of the universities to generate researchers and carry out R&D, and has proposed a series of manpower measures designed to remedy the weakened capacity. The Council's plan provides for a large number of research associateships at the universities, and support for researchers destined for the industrial sector.

TABLE 6

ESTIMATES OF THE NUMBER OF AVAILABLE Ph.D.s AND M.Sc.s POST-GRADUATES (ADJUSTED SUPPLY)

(Natural Sciences)

	APPLIED SCIENCE	OTHER SCIENCES	TOTAL NATURAL SCIENCE
1972	2,560	1,783	4,343
1973	2,704	1,796	4,500
1974	2,483	1,686	4,169
1975	2,313	1,530	3,842
1976	2,235	1,362	3,597
1977	2,351	1,319	3,671

SOURCE: Based on Appendix Tables A-5 to A-7

The government also has recognized the importance of the role played by the universities in the attainment of the national science effort, by establishing an R&D target that is substantially higher than the current level of R&D spending, and by instituting measures designed to raise industrial R&D to a level that will render industry competitive internationally.

Given the NSERC manpower measures, and given the government's position on the support for industrial R&D, one might expect that the factors that are now depressing the level of research training in the universities can be countered, and that the declining trends can be reversed. For purposes of this study, it is assumed that there will be no further declines in graduate enrolments over the projected period.

Specifically, the levels for 1977 are assumed to prevail for the projection period. Table 7 summarizes the aggregate supply totals anticipated to be available. These are degrees granted, adjusted for immigration and Canadians returning home, and for foreign students, part-time students and those remaining enrolled for further studies.

REQUIREMENTS FOR R&D PERSONNEL AND THE AVAILABILITY OF RESEARCHERS

In this section, the requirements are compared to the number of Ph.D.s and Masters that have been projected for the two time periods. As a starting point in the analysis of possible imbalances, it is assumed that all new R&D jobs would have to be staffed by research trained university graduates. This rather restrictive assumption merely serves to delineate the extent of imbalances if only persons with post-graduate degrees were to be used. But as noted earlier, while the majority of researchers working in the universities and in government have post-graduate degrees, this is the case for only about one-third of the researchers working in industry. There is evidence that the proportion of persons with post-graduate degrees hired by industry for R&D jobs has been rising in recent years[4].

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[4]Ministry of State for Science and Technology, "The Stock of Research Trained Personnel", Background paper no. 16.

TABLE 7

PROJECTED AVAILABLE SUPPLY OF Ph.D.s AND M.Sc.s

(Cumulative Totals)

	APPLIED SCIENCES	OTHER NATURAL SCIENCES	TOTAL
1978-1985	16,450	9,240	25,690
1985-1990	11,750	6,600	18,350
TOTAL	28,200	15,840	44,040

SOURCE: Based on Appendix Tables A-6 and A-7. 1977 data are accumulated for number of years in projected periods.

A summary of the differences between the requirements for researchers and the availability of Ph.D.s and Masters in the various GERD scenarios is provided in Table 8. The table also shows the implications of varying the R&D/researcher and length of work life assumptions. The imbalances implied for applied natural science researchers and for researchers in the applied sciences is illustrated in Table 9, which shows balances for the highest and lowest combinationsof the assumptions.

In the 1.5/1985 scenario, over the period to 1985, assuming 3 percent growth in the R&D/researcher ratio, and making the restrictive assumption that all new R&D jobs would have to be staffed with research trained personnel, there would be a cumulative shortage of about 4,050 research-trained, and most of these would be from the applied fields of science (2,960). Stretching the 1.5 percent GERD target to 1990 would, under these assumptions, not result in shortages. The estimates are based on 1.5 percent attrition, and the work life assumption that a researcher, having entered an R&D career, would remain in it.

Raising GERD to 2.5 percent of GNP by 1990 implies a shortfall in supply of about 22,515 graduates over the decade, again under the restrictive assumption that all R&D jobs would have to be staffed by R&D trained personnel, and given that R&D/researcher will grow at 3 percent. The attrition and work-life assumptions are as above. In this scenario, there is significant growth in university and government research, although the major expansion takes place in industrial R&D. The suggested supply shortfall, therefore, occurs largely in the applied sciences (13,610), but there are substantial shortfalls in the fundamental sciences as well (8,905) (see Table 9).

The calculations (Table 9) are based on the restrictive assumption that R&D jobs will have to be staffed by research trained personnel (i.e., by Masters and Ph.D.s). In the past, however, only about one-third of professional researchers engaged by industry in R&D jobs had post-graduate research training, the balance having other qualifications. The calculations would tend to be over-estimates to the extent that industry continues to staff R&D jobs in the traditional pattern, i.e., by using new B.Sc.s, engineers, or by retraining persons in the work force. While a significant proportion of the R&D manpower requirements could be met in this way, there would still

TABLE 8

DIFFERENCES BETWEEN REQUIREMENTS FOR RESEARCHERS AND AVAILABILITY OF Ph.D.s AND MASTERS, UNDER THE VARIOUS GERD SCENARIOS AND ASSUMPTIONS

		1978-85		1978-1990		
GERD SCENARIOS		0.95/85	1.5/85	0.95/90	1.5/90	2.5/90
1.5% Attrition, full life-time R&D career	3.0% growth in R&D/researcher	9,815	- 4,050	17,345	3,015	-22,515
	1.5% growth in R&D/researcher	7,255	- 8,090	12,635	- 4,380	-34,730
	No growth in R&D/researcher	4,380	-12,630	6,945	-13,315	-49,490
1.5% Attrition, 15 year R&D work life	3.0% growth in R&D/researcher	- 915	-14,785	- 1,055	-15,380	-40,915
	1.5% growth in R&D/researcher	-3,475	-18,820	- 5,765	-22,780	-53,130
	No growth in R&D/researcher	-6,355	-23,360	-11,450	-31,710	-67,890

SOURCE: MOSST estimates.

NOTE: (-) Indicates a shortfall in the number of available Ph.D.s and M.Sc.s.

GERD Scenarios: 1.5/85 means that GERD is assumed to be 1.5% of GNP in 1985, etc.

TABLE 9

DIFFERENCES BETWEEN REQUIREMENTS FOR RESEARCHERS

AND AVAILABILITY OF Ph.D.s AND MASTERS IN

APPLIED AND OTHER THAN APPLIED NATURAL SCIENCES

(Cumulative Totals)

GERD SCENARIOS		1978-85 0.95/85	1978-85 1.5/85	1978-90 0.95/90	1978-90 1.5/90	1978-90 2.5/90
3% growth in R&D/ researcher, and 1.5% attrition	Applied Natural Sciences	4,920	- 2,960	9,035	900	-13,610
	Other Natural Sciences	4,895	- 1,090	8,310	2,120	- 8,905
	TOTAL	9,815	- 4,050	17,345	3,020	-22,515
No growth in R&D/ researcher, Productivity Growth/ 1.5% attrition and 15 year work life	Applied Natural Sciences	-4,035	-13,700	- 6,925	-18,435	-38,995
	Other Natural Sciences	-2,320	- 9,660	- 4,525	-13,275	-28,895
	TOTAL	-6,355	-23,360	-11,450	-31,710	-67,890

SOURCE: MOSST estimates.

NOTE: (-) Indicates a shortfall in the number of available Ph.D.s and M.Sc.s.

GERD Scenarios: 1.5/85 means that GERD is assumed to be 1.5% of GNP in 1985, etc.

remain large areas of shortages. For example, the number of new engineering graduates coming out of the universities at the present time is now about equal to the labour market needs (if some minor skill mis-matches are ignored). Without significant expansion of the engineering training capacity, this source of meeting R&D manpower shortages could therefore be a limited one[5].

Any remaining shortages would have to be made up of a combination of the pull on additional enrolment exerted by the emergence of new research jobs and careers, especially in industry; and on-the-job research training by industry, perhaps with the cooperation of universities. Also, there would have to be selective increases in immigration. The number of immigrants in the natural sciences fields is estimated to have fallen from over 1,000 per year at the beginning of the 1970s to about one-half that level at the end of the 1970s (see Appendix Table A-5). If more immigrants in this field can be attracted, they would have to be used more strategically to transfer knowledge and skills to Canadians, in order to increase the Canadian pool of skill and experience on a more permanent basis. Finally, any shortages would have to be addressed also by further increases in the NSERC Manpower programs.

To sum up, the calculations presented here indicate that the achievement of a higher GERD target is predicated on a number of factors that would require careful planning and management. An ambitious GERD target, or a target aimed at a very early date, or failure to attract and retain researchers, would soon result in shortages of research personnel, especially in the applied sciences. On the other hand, a continuation of the low level of GERD that now prevails will result in surpluses of research trained graduates, unless there were further sharp declines in graduate enrolments at Canadian universities. Such declines, however, would further aggravate the problems and shortages of Canada's national R&D capacity.

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[5] As further support for this theme, a recent study by the Ontario Ministry of Colleges and Universities indicates that a substantial increase in research and development activity would place a preponderant burden on all engineering programs at the post-graduate level. (Ontario Ministry of Colleges and Universities, "Polytechnic Education in Ontario", September 1980.)

STATISTICAL APPENDIX

Table A-1

PROJECTION OF GROSS NATIONAL PRODUCT (GNP)
1978 TO 1990

(BILLION 1978 DOLLARS)

	CONSTANT DOLLARS
1978	230.4
1979	237.3
1980	244.4
1981	251.8
1982	259.3
1983	267.1
1984	275.1
1985	283.4
1986	291.9
1987	300.6
1988	309.6
1989	318.9
1990	328.5

NOTE: Estimates based on data provided to MOSST by the Department of Finance.

TABLE A-2

NUMBER OF RESEARCHERS BY PERFORMING SECTOR
1975 AND 1978

PERFORMER	1975			1978		
	VALUE OF R&D PERFORMED ($ MIL)	NUMBER OF RESEARCHERS	$ R&D PER RESEARCHER	VALUE OF R&D PERFORMED ($ MIL)	NUMBER OF RESEARCHERS	$ R&D PER RESEARCHER
FEDERAL GOVERNMENT (A)	466.4	5,638	82,724	606.9	5,866	103,461
PROVINCIAL GOVERNMENT (B)	55.8	675	82,724	73.7	712	103,461
INDUSTRY (C)	696.5	8,299	83,926	927.5	10,091	90,918
UNIVERSITIES (D)	435.7	4,792	90,922	555.2	4,990	111,263
PRIVATE NON-PROFIT (B)	11.6	140	82,724	14.7	142	103,461
TOTAL	1,666.0	19,544	85,244	2,178.0	21,801	99,904

SOURCE: STATISTICS CANADA, SCIENCE STATISTICS CENTRE AND MOSST, UNIVERSITY BRANCH.

(a) (A) MOSST, FEDERAL SCIENCE EXPENDITURES AND MANPOWER, 1977 AND 1979 SURVEYS. INCLUDES SCIENTIFIC AND PROFESSIONAL, ADMINISTRATIVE AND FOREIGN SERVICES, EXECUTIVE AND MILITARY OCCUPATIONS.

(b) (B) PROVINCIAL AND PRIVATE NON-PROFIT MANPOWER ESTIMATES BASED ON R&D PER RESEARCHER IN FEDERAL GOVERNMENT.

(c) (C) STATISTICS CANADA, INDUSTRIAL SURVEY. 1978 ESTIMATE OF RESEARCHERS BASED ON TREND IN R&D PER RESEARCHER, 1971 TO 1977.

(d) (D) STATISTICS CANADA, UCASS FILE; THE NUMBER OF FULL-TIME UNIVERSITY TEACHERS IN HEALTH, NATURAL SCIENCES AND ENGINEERING.

(e) NOTE: THE NUMBER OF RESEARCHERS SHOWN FOR THE YEAR 1978 MAY DIFFER SLIGHTLY FROM MORE RECENT DATA PUBLISHED BY STATISTICS CANADA, "ANNUAL REVIEW OF SCIENCE STATISTICS, 1979".

TABLE A-3

PROJECTION OF REAL R&D EXPENDITURES PER RESEARCHER OF 3% PER YEAR
1978 TO 1990

(CONSTANT 1978 DOLLARS)

	FEDERAL GOVERNMENT	PROVINCIAL GOVERNMENT	INDUSTRY	UNIVERSITIES	PRIVATE NON-PROFIT
1978	103,461	103,461	90,918	111,263	103,461
1979	106,565	106,565	93,646	114,601	106,565
1980	109,762	109,762	96,455	118,039	109,762
1981	113,055	113,055	99,349	121,580	113,055
1982	116,446	116,446	102,329	125,227	116,446
1983	119,940	119,940	105,399	128,984	119,940
1984	123,538	123,538	108,561	132,854	123,538
1985	127,244	127,244	111,818	136,839	127,244
1986	131,061	131,061	115,172	140,945	131,061
1987	134,993	134,993	118,627	145,173	134,993
1988	139,043	139,043	122,186	149,528	139,043
1989	143,214	143,214	125,852	154,014	143,214
1990	147,511	147,511	129,627	158,634	147,511

SOURCE: BASED ON DATA SHOWN IN APPENDIX TABLE A-2.

TABLE A-4

RESEARCHERS REQUIRED BY SECTOR UNDER VARIOUS ASSUMPTIONS
(FULL-TIME EQUIVALENT PERSON YEARS)

(NUMBER OF PERSONS)

		1978 STOCK	TARGET REACHED BY 1985		TARGET REACHED BY 1990		
			0.95/85	1.5/85	0.95/90	1.5/90	2.5/90
3% GROWTH IN R&D/RESEARCHER	FEDERAL	5,866	3,191	5,065	3,191	5,065	8,442
	PROVINCIAL	712	625	992	625	992	1,653
	INDUSTRIAL	10,091	15,568	24,711	15,568	24,711	41,185
	UNIVERSITY	4,990	3,183	5,052	3,183	5,052	8,421
	PRIVATE NON-PROFIT	142	124	198	124	198	330
	TOTAL	21,801	22,691	36,018	22,691	36,018	60,031
NO GROWTH IN R&D/RESEARCHER	FEDERAL	5,866	3,924	6,256	4,549	7,221	12,036
	PROVINCIAL	712	768	1,220	891	1,414	2,357
	INDUSTRIAL	10,091	19,147	30,392	22,196	35,232	58,721
	UNIVERSITY	4,990	3,914	6,214	4,538	7,204	12,005
	PRIVATE NON-PROFIT	142	153	243	177	282	470
	TOTAL	21,801	27,906	44,325	32,351	51,353	85,590

SOURCE: ESTIMATES BY MOSST

(a) NOTE: ATTRITION (REPLACEMENT DEMAND) ASSUMPTIONS DO NOT AFFECT THE SIZE OF THE R&D PERSONNEL STOCK BY SECTOR AND ARE THEREFORE EXCLUDED FROM THIS TABLE.

TABLE A-5

NATURAL SCIENCE GRADUATES - 1972 TO 1977

ALL NATURAL SCIENCE FIELDS

	DEGREES AWARDED	LESS			DOMESTIC SUPPLY	ADD		AVAILABLE SUPPLY
		PART-TIME	FOREIGN STUDENTS	CONTINUING EDUCATION		RETURNING CANADIANS	IMMIGRANTS	
1972	4,026	293	545	467	2,721	689	932	4,343
1973	4,036	465	536	414	2,621	689	1,150	4,500
1974	3,677	471	491	360	2,355	624	1,190	4,169
1975	3,599	547	470	355	2,227	591	1,024	3,842
1976	3,737	735	427	377	2,198	614	784	3,597
1977	4,040	816	445	424	2,355	678	638	3,671

SOURCE: Based on data published by Statistics Canada, "Universities: Enrolment and Degrees", Cat. No. 81-204, Annuals 1975-1978" and "Degrees, Diplomas and Certificates Awarded by Universities", Cat. No. 81-211, Annuals 1972-1975, Education, Science and Culture Division, Ottawa.

TABLE A-6

NATURAL SCIENCE GRADUATES - 1972 TO 1977

APPLIED FIELDS OF STUDY

	DEGREES AWARDED	LESS			DOMESTIC SUPPLY	ADD		AVAILABLE SUPPLY
		PART-TIME	FOREIGN STUDENTS	CONTINUING EDUCATION		RETURNING CANADIANS	IMMIGRANTS	
1972	2,357	199	349	243	1,566	419	574	2,559
1973	2,453	325	348	229	1,551	432	721	2,704
1974	2,205	324	333	187	1,361	386	736	2,483
1975	2,149	363	298	186	1,302	358	652	2,312
1976	2,303	492	271	200	1,340	387	508	2,235
1977	2,607	585	297	236	1,489	446	416	2,351

SOURCE: Based on data published by Statistics Canada, "Universities: Enrolment and Degrees", Cat. No. 81-204, Annuals 1975-1978" and "Degrees, Diplomas and Certificates Awarded by Universities", Cat. No. 81-211, Annuals 1972-1975, Education, Science and Culture Division, Ottawa.

TABLE A-7

NATURAL SCIENCE GRADUATES - 1972 TO 1977

OTHER (FUNDAMENTAL) FIELDS OF STUDY

	DEGREES AWARDED	LESS			DOMESTIC SUPPLY	ADD		AVAILABLE SUPPLY
		PART-TIME	FOREIGN STUDENTS	CONTINUING EDUCATION		RETURNING CANADIANS	IMMIGRANTS	
1972	1,669	94	196	224	1,155	270	358	1,783
1973	1,583	140	188	185	1,070	257	469	1,796
1974	1,472	148	158	172	994	238	454	1,686
1975	1,450	183	172	170	925	233	372	1,530
1976	1,434	243	156	177	858	227	277	1,362
1977	1,433	231	149	187	866	232	221	1,319

SOURCE: Based on data published by Statistics Canada, "Universities: Enrolment and Degrees", Cat. No. 81-204, Annuals 1975-1978" and "Degrees, Diplomas and Certificates Awarded by Universities", Cat. No. 81-211, Annuals 1972-1975, Education, Science and Culture Division, Ottawa.